

Geopolitical versus Ecological Frameworks and Soil Resource Assessment

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ABSTRACT

A Soil Diversity Index (SDI) was developed to compare the diversity of soils in natural ecological / soil landscapes with the diversity in geopolitical units. U.S. counties were chosen to represent the geopolitical framework. Major Land Resource Areas (MLRAs) were chosen as the ecological framework. This SDI uses the Soil Root Zone Available Water Capacity (RZAWC) as the soil quality or attribute being assessed. The SDI uses area of soils mapped in each of 14 categories of RZAWC as the importance value (Table 1). The volume of soil RZAWC for each category is divided by the total county soil RZAWC, squared, and summed for all categories. The reciprocal of this value results in the SDI for the geopolitical and ecological frameworks. The indices calculated for the geopolitical and ecological frameworks considered all soils. The geopolitical framework was calculated for the 48 conterminous states. There was greater diversity in the soil RZAWC for counties than for parts of MLRAs within counties. The greater SDI values for counties suggest that ecological / soil units might be more useful for conducting equitable resource assessments than geopolitical units.

INTRODUCTION

A Soil Diversity Index (SDI) was developed to compare the diversity of soils within an ecological / soil landscape framework (ecoregions / soil regions) and the diversity of soils within a geopolitical framework (counties). This index was developed as a possible tool to help provide greater consistency and equity in conducting resource assessments and applying conservation programs (Photos 1-3). MLRAs were chosen as the ecological framework. MLRAs are geographically associated land resource units delineated by the Natural Resources Conservation Service and characterized by a particular pattern that combines climate, terrain, soils, water, potential vegetation, land use, and type of farming. There are 188 MLRAs in the conterminous United States. Nationally, MLRAs may range in size from less than 500,000 acres to more than 60 million acres (USDA-NRCS, Staff, 1981). U.S. counties were chosen as the geopolitical framework. The SDI values calculated for the geopolitical and ecological frameworks considered all mapped soils in the 48 conterminous states.

The SDI is based on a species diversity index commonly used by ecologists to measure plant and animal diversity (Gleissman, 1998; Odum, 1993; Southwest Texas State University, 2000; University of Missouri, 2000; University of Maryland, 2000; Whittaker, 1975). The index of diversity chosen for adaptation to soil diversity is the inverse of the Simpson index of community dominance. It is based on the principle that a system is most diverse when none of its component species can be considered more dominant than any other.

When developing an SDI, it is important to remember that one is trying to describe the diversity (the condition of being different) of soil attribute values for a given region, e.g., county or MLRA. An SDI can be calculated for RZAWC, bulk density, pH, texture, or any other attribute considered important for a soil resource assessment. The SDI allows for comparisons of the innate heterogeneity or homogeneity for geographical regions of any extent. A region that is heterogeneous consists of dissimilar constituents, whereas a region that is homogeneous consists of uniform constituents. The SDI does not indicate the actual magnitude of the attribute, only how variable the attribute is within a geographic area. The SDI alone provides no information about the underlying values of the attribute.

Important underlying SDI assumptions include:

- A reliable measured or estimated value for the soil attribute being assessed is available for the study area.
- The range of category values do not overlap. That is, each category must have a unique range of numerical values.
- The chosen soil attribute is well-correlated to the soil resource assessment being performed.

METHODS

We used Soil Root Zone Available Water Capacity (RZAWC) to compute an SDI_{RZAWC} . The SDI_{RZAWC} uses area of soil mapped in categories of RZAWC as the importance value. Categories of RZAWC are analogous to plant or animal species in the ecologist's Simpson Index calculations. The full range of the soil RZAWC for the conterminous U.S. was partitioned into 14 categories used to calculate the SDI_{RZAWC} (Table 1).

The arithmetic procedures to calculate any SDI are shown in Equation 1. A value of 1 (one) indicates the absence of diversity. This condition could exist in a soil survey area with only one category for a soil attribute. In theory, the maximum value for an index is limited only by the number of different categories (Gleissman, 1998). The equation for diversity is (Gleissman, 1998; Whittaker, 1975; University of Missouri, 2000; Odum, 1993):

$$\text{Equation 1:} \quad \text{Soil Diversity Index (SDI)} = \frac{1}{D} = \frac{1}{\sum (n_i/N)^2}$$

Where:
 n_i is the number or other important value
 N is the sum of importance values

RZAWC was chosen for analysis because it is an attribute important to many soil and agronomic resource assessments (Photo 4). In calculating RZAWC, effective root zone depth was determined using the methods recommended by Soil Survey Staff (2000). The calculated RZAWC for counties in the continental US (Soil Survey Staff, 1997a) are shown on Map 1 and listed in Figure 1.

Using the procedures shown in Table 2, the SDI_{RZAWC} was calculated for 2,909 counties in the U.S. using detailed soil survey data (Soil Survey Staff, 1997a). Values were not calculated for 202 counties due to missing or incomplete data.

A more detailed analysis was conducted for four counties representing major regions of the U.S. using the digital soil survey geographic database or SSURGO (Soil Survey Staff, 1995; 1997b; 1998a; 1998b; 1999). See Map 2. Based on the initial SDI_{RZAWC} analysis, we selected four counties expected to differ significantly in soil heterogeneity. SDI was calculated for each entire county and then for each of the individual MLRA units within each county. MLRA units were determined using general soil maps at a scale of 1:250,000 (Soil Survey Staff 1994).

RESULTS & DISCUSSION

I. National

SDI_{RZAWC} values of counties within the conterminous U.S. range from 1.00 to 10.87 (See Map 3 and Figure 2).

Some plant ecologists have determined that diversity indices > 5 indicate high levels of heterogeneity (Gleissman, 1998). However, we have not yet assessed the applicability of this threshold to soils. On a county-wide basis, approximately 52 percent of the area assessed in this study has SDI_{RZAWC} values > 5.

II. County

In preliminary results, SDI_{RZAWC} for the county samples ranged from 1.82 for DeKalb County, Missouri, to 10.40 for Sacramento County, California (Table 3). These two counties have about the same mean RZAWC. However, the variability within each county is quite different, as shown by their differing SDI_{RZAWC} values.

Figures 3 through 6 illustrate the areal distribution of RZAWC for each sample county. SDI_{RZAWC} values appear to be a good indicator of the character of these distributions. Low values indicate counties in which one or two categories dominate on an area basis, as shown in DeKalb County, Missouri (Figure 3). Mid-range values appear to indicate a more even distribution among categories, as shown in Grant County, Washington (Figure 4). Higher-range values appear to indicate a relatively even distribution among nearly all categories of RZAWC, as shown in Chesterfield County, South Carolina, and Sacramento County, California (Figures 5 and 6).

The SDI_{RZAWC} , when used in conjunction with a mean or other measure of central tendency, can describe the geographic distribution of RZAWC and convey information about the diversity of the soil attribute that would otherwise require a digital map or more complex statistical summary.

We suggest that an SDI can provide information useful in selecting an appropriate geographical region for conducting equitable assessments of soil resources.

Table 1. Soil Root Zone Available Water Capacity (RZAWC) for the Conterminous U.S.

Category	Soil Root Zone Available Water Capacity centimeters	inches
1	< 2.5	< 1
2	2.5 < 5.1	1 < 2
3	5.1 < 7.6	2 < 3
4	7.6 < 10.2	3 < 4
5	10.2 < 12.7	4 < 5
6	12.7 < 15.2	5 < 6
7	15.2 < 17.8	6 < 7
8	17.8 < 20.3	7 < 8
9	20.3 < 22.9	8 < 9
10	22.9 < 25.4	9 < 10
11	25.4 < 27.9	10 < 11
12	27.9 < 30.5	11 < 12
13	30.5 < 35.6	12 < 14
14	35.6 < 106.7	14 < 42

Table 2. Example of the SDI_{RZAWC} calculation for a region with two RZAWC categories.

Root Zone Category	AWC (in/in)	Depth (in)	Area in Acre(s) (6.3 x 10 ⁶ in ² /acre)	RZAWC Volume (in ³ /acre) [n _i (1x 10 ⁶)]
7	0.10	60	1	37.8
13	0.20	60	1	75.6
				N = 113.4
$SDI_{RZAWC} = \frac{1}{\sum (n_i/N)^2} = \frac{1}{(37.8/113.4)^2 + (75.6/113.4)^2} = \frac{1}{0.556} = 1.8$				

Table 3. County characteristics and SDI_{RZAWC} results for entire county versus portions of MLRA units within county.

County	County Area km ² (mi ²)	¹ County Mean RZAWC cm (in)	MLRA Mean RZAWC cm (in)	County SDI_{RZAWC}	² MLRA SDI_{RZAWC}	Major Land Resource Area
DeKalb Co., MO	1,092 (420)	19.4 (7.6)	18.0 (7.1)	1.82	1.82	109 - Iowa & Missouri Heavy Till Plain
Grant Co., WA	7,216 (2,776)	15.8 (6.2)	15.3 (6.0)	5.80	3.33	7 - Columbia Basin
			8 (7.4)		3.18	8 - Columbia Plateau
Chesterfield Co., SC	2,059 (792)	13.9 (5.3)	14.0 (5.5)	6.84	2.93	136 - Southern Piedmont
			7 (3.8)		1.82	137 - Carolina & Georgia Sand Hills
			.6 (8.1)		3.53	133A - Southern Coastal Plain
Sacramento Co., CA	2,587 (995)	24.5 (9.6)	31.2 (12.3)	10.40	3.97	16 - California Delta
			.7 (4.6)		6.97	17 - Sacramento & San Joaquin Valleys
			4 (2.1)		2.66	18 - Sierra Nevada Foothills

¹ Value computed using the National MUIR data source (Soil Survey Staff, 1997a).

² Value computed using the MLRA regions derived from county general soil map (STATSGO) digital detailed soil map (SSURGO) sources (Soil Survey Staff, 1994; 1997b; 1998a; 1998b; 1999).

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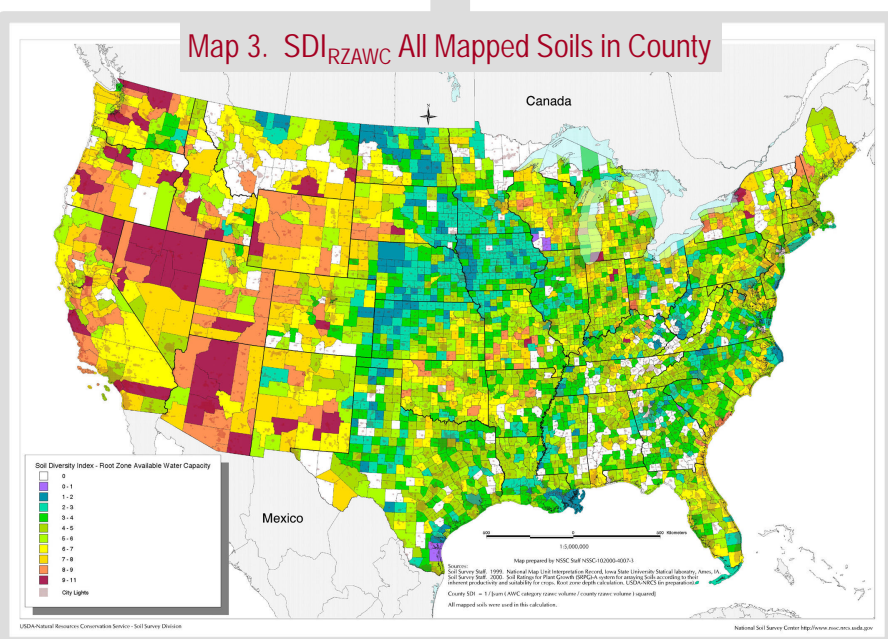
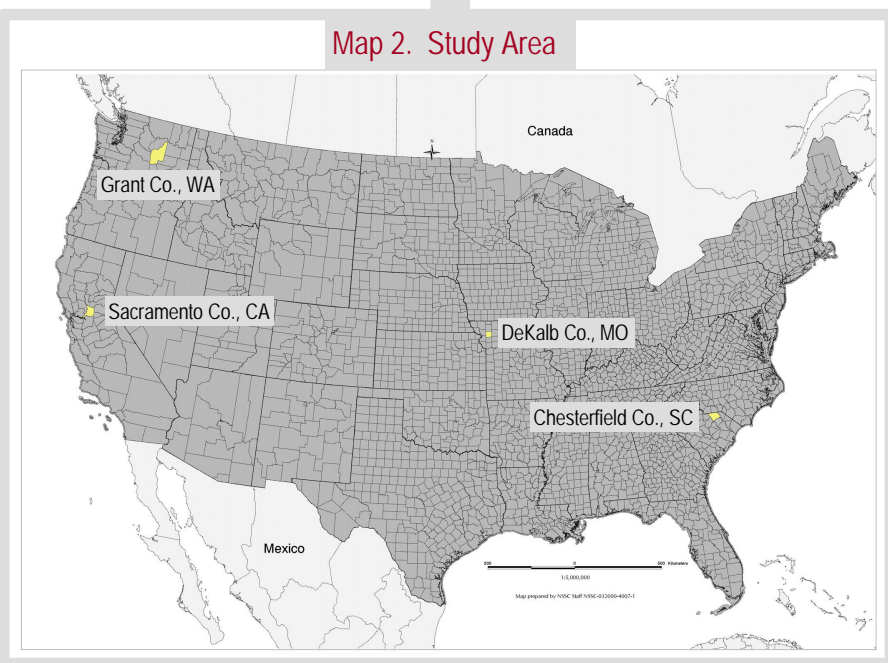
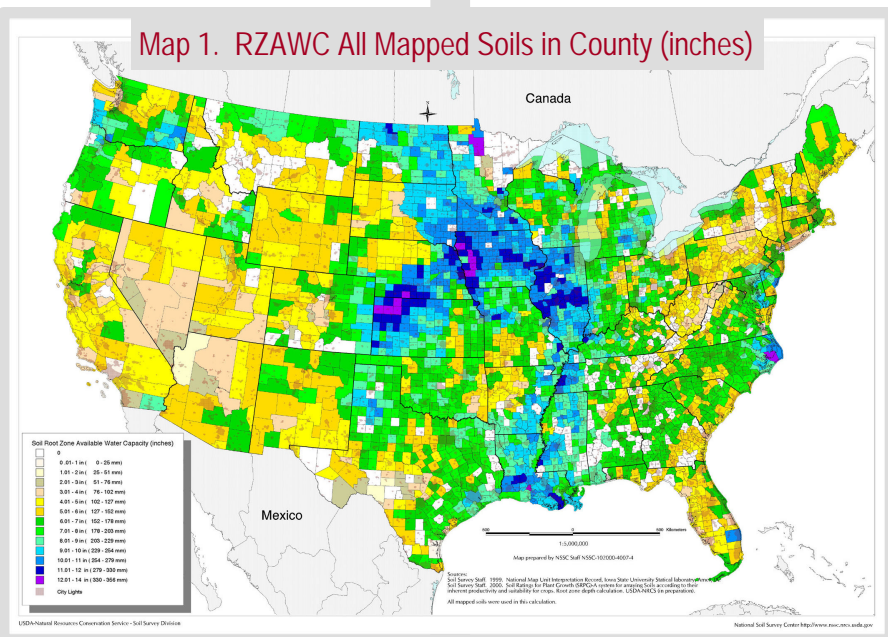


Figure 1. Area distribution RZAWC for the conterminous U.S.

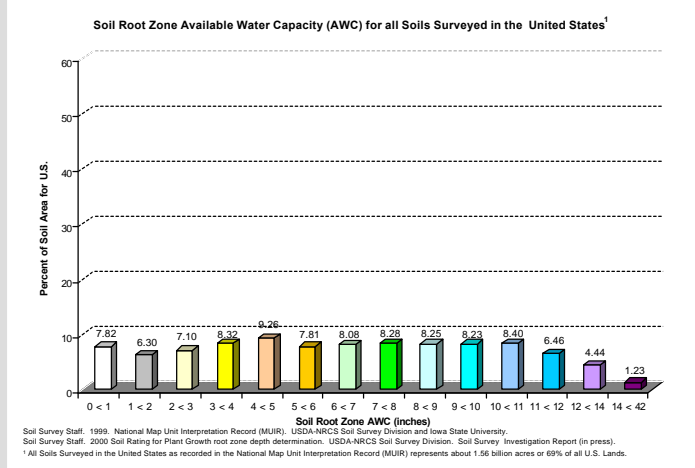


Figure 2. Area distribution of the SDI RZAWC for the conterminous U.S.

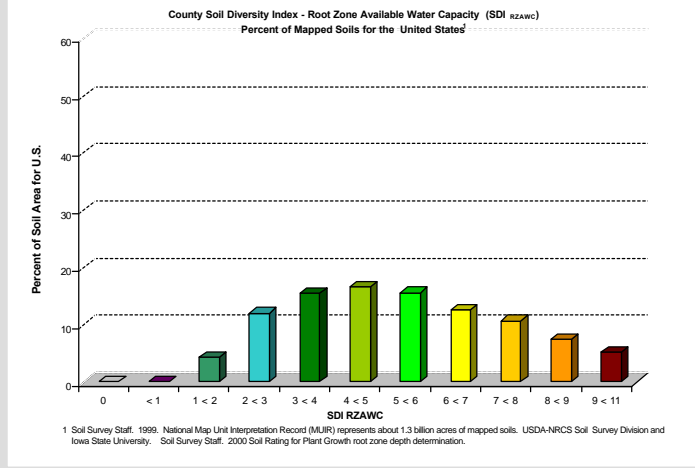


Figure 3. Area distribution of RZAWC for DeKalb County, Missouri.

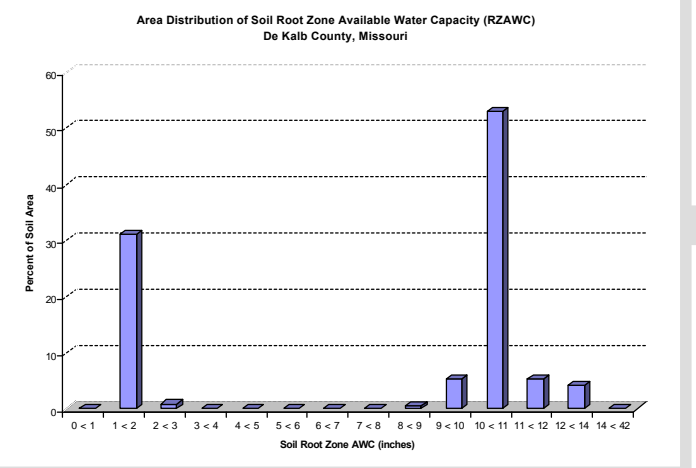


Figure 4. Area distribution of RZAWC for Grant County, Washington.

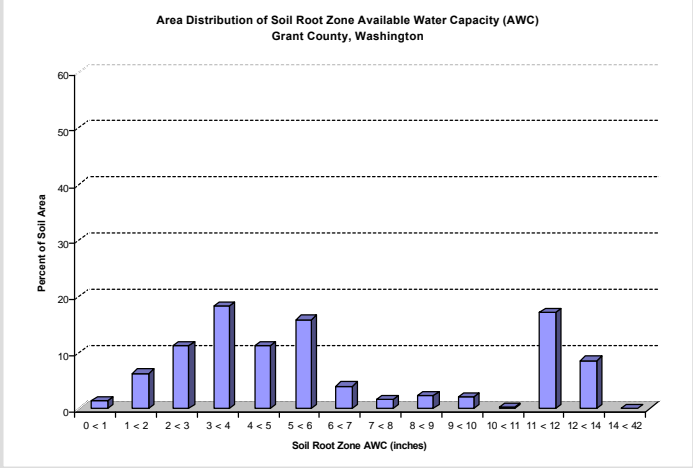


Figure 5. Area distribution of RZAWC for Chesterfield County, South Carolina.

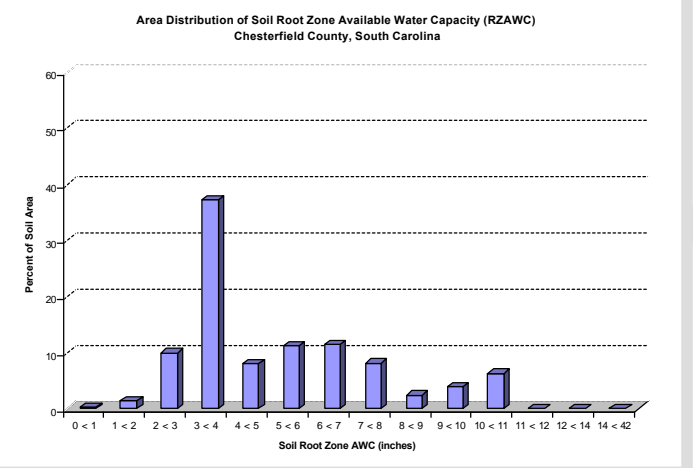


Figure 6. Area distribution of Sacramento County, California.

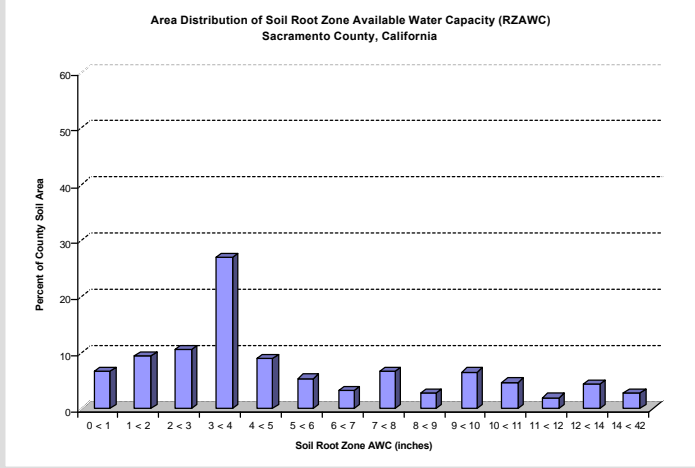


Photo 1. Soil resource assessments for agroecological approaches to conservation planning.



Photo 2. Soil resource assessments for environmentally sound approaches to nutrient management.



Photo 3. Soil resource assessments for preserving highly productive farm lands to sustain and secure food supplies.



Photo 4. Deep root zone soils (left) provide greater available water capacity (AWC) than shallow root zone soils (right).

